

active magnetic antennas

*have general coverage receiver,
will travel*

The combination of a wire loop with the size of an A4 sheet, coupled to a carefully matched and easily tuned amplifier offers high-quality

MW/LW/SW radio reception in your living room. The excellent performance of the two 'all-portable' directional active antennas described in this article makes them direct rivals of many extensive outdoor antennas. Meet the Omega-2 and Omega-3!

Designs by
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The active antenna designs discussed in this article are the result of many years of comparative signal level monitoring using various long-wave, medium-wave and short-wave antennas for indoor and outdoor use. The antennas available for this research work were a 5-m high vertical ground plane, a magnetic loop with a diameter of 1.2 m, an active 'rod' antenna [1] and various small magnetic antennas including round and square loops, and ferrite rods coupled to suitably dimensioned amplifiers.

General antenna theory tells us that long wires and rod antennas are only sensitive to the electric component of

the received signal. When used indoors, they loose 70-90% of the received voltage as compared with a mounting position on the roof. By contrast, small loop-antennas exhibit a totally different behaviour, mainly because they are sensitive to the magnetic component of the RF signal produced by the transmitter. As long as the thickness of the 'wall' or other obstacle to be traversed is much smaller than the wavelength, a magnetic field is hardly reduced in strength. Consequently, the level differences between magnetic antennas mounted indoors and outdoors were found to range from negligible to 50% at the highest

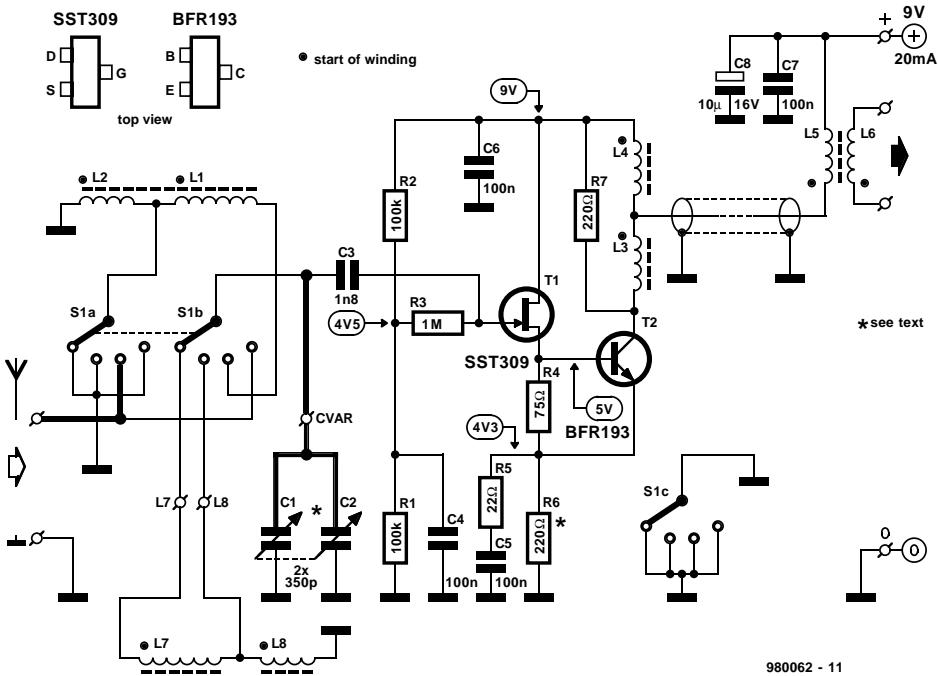


Figure 1. Circuit diagram of the Omega-2 active magnetic antenna for LW/MW/SW reception from 150 kHz to 30 MHz in four ranges. Note that the amplifier is only suitable for the indicated loop antenna. The heavy lines in the diagram indicate connections made in solid wire to preserve the Q factor of the antenna.

$$\frac{U_{out}}{E} = \frac{2\pi f}{c} \cdot \frac{n_{(L_2)} + n_{(L_1)}}{n_{(L_1)}} \cdot A_{loop} \cdot Q \cdot G$$

where $c = 3 \cdot 10^8 \text{ m/s}$

$$A = 0.05 \text{ m}^2$$

$$G \approx \frac{1}{2} \cdot \frac{R_7 // 4.5 \Omega}{R_5 + r_D \left[1 + \frac{R_5 + 1/g_f}{\beta \cdot r_D // R_4} \right]}$$

With $r_D \approx 25 \text{ mV} / I_c = 2.5 \Omega$ at $I_c = 10 \text{ mA}$, $\beta = 100$, and FET transconductance $g_f = 17 \text{ mS}$, we get $G \approx 1.9$

With $Q = 50$ (at 10 MHz) the effective antenna height is $\frac{U_{out}}{E} = 1.0 \text{ m}$

on one occasion.

There are still other marked differences between antennas responding to the 'electric' field, and their counterparts designed to convert the magnetic component into an electric voltage. Whereas the currently popular active electric antenna (say, the combination of the small telescopic rod with a matching amplifier) typically exhibits wideband behaviour, magnetic antennas generate competitive voltage levels only in resonance, that is, when accurately tuned to the desired receive frequency. Wideband systems unfortunately suffer from susceptibility to intermodulation in the vicinity of strong transmitters, a problem that calls for rather special remedy [2]. Another advantage of magnetic active antennas is that they supply an RF signal with an unusually low background noise level.

W-2 ANTENNA FOR LW/MW/SW

The first antenna discussed here provides seamless coverage of the

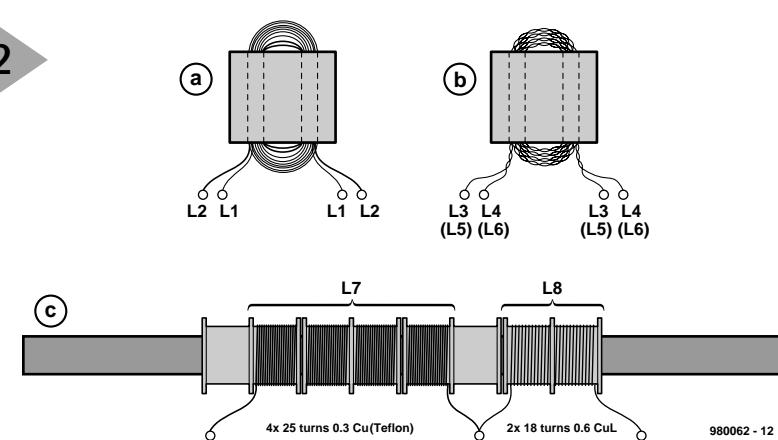
LW/MW/SW frequency range from 150 kHz to 30 MHz. It is powered by either the receiver or its own power supply, via the RF output cable and a simple RF/DC splitter. Current consumption will be of the order of 20 mA at a supply voltage of 9 V or 12 V. The amplifier accepts a number of inductive loops and coils,

including experimental ones, which are simply 'plugged in'.

The electronics

Although the two-stage amplifier shown in Figure 1 is based on the design presented in [1], a short discussion on its opera-

Figure 2. Construction details of the transformers and the LW/MW rod antenna used in the Omega-2.



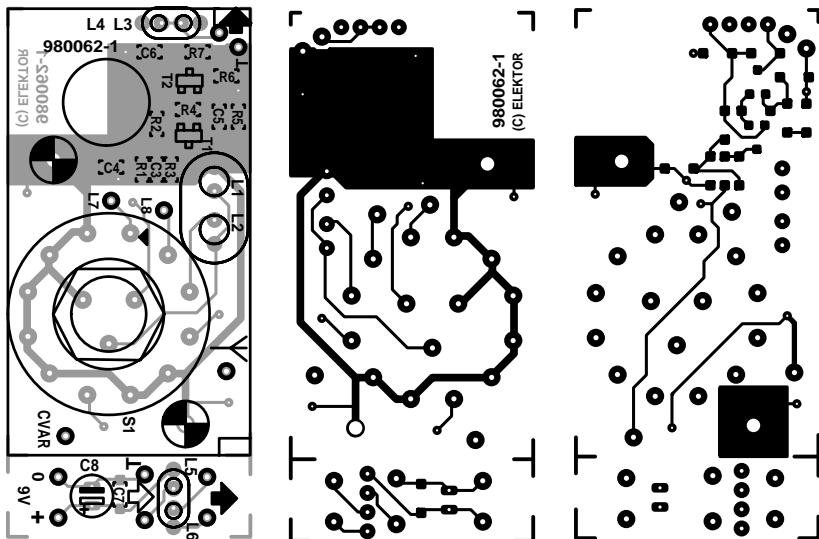


Figure 3. Copper track layouts and component mounting plan of the double-sided, not through-plated PCB. Board available ready-made from the Publishers.

COMPONENTS LIST

Resistors:

R1,R2 = 100k Ω SMA
R3 = 1M Ω SMA
R4 = 75 Ω SMA
R5 = 22 Ω SMA
R6 = 220 Ω (9V supply) or 330 Ω (12V supply)
R7 = 220 Ω

Capacitors:

C1+C2 = one 700-pF tuning capacitor, made from two 350-pF AM sections.
C3 = 1nF8 or 2nF2 SMA
C4-C7 = 100nF SMA
C8 = 10 μ F 16V radial

Inductors:

(CuL = enamelled copper wire)
L1 = 14 turns 0.4mm dia. CuL on binocular core 14x8x8mm, material K1, purple (Siemens)
L2 = 4 turns 0.6mm dia. CuL on above core.
L3 = 10 turns 0.15mm CuL on binocular core 7x6x4mm, material N30, white (Siemens)
L4 = 10 turns 0.15mm CuL on above core (bifilar)
L5 = 10 turns 0.15mm CuL on binocular core 7x6x4mm, material N30, white (Siemens)
L6 = 10 turns 0.15mm CuL on above core (bifilar)
L7 = 100 (4x25) turns 0.3mm dia. AWG30 Teflon-coated wire (Tefzel) on two 2-compartment formers for pot cores 26dia.x16mm.
L8 = 36 (2x18) turns 0.6mm CuL on 2-compartment former for pot cores 26dia.x16mm.
Ferrite rod, 10x200mm, material 4B1 (Philips Components, order code 43300303071)
4 off 2-compartment formers for 26dia.x16mm pot cores.

Semiconductors:

T1 = SST309 (Siliconix, Temic)

T2 = BFR193 (Siemens)

Miscellaneous:

S1 = rotary switch, 3 poles, 4 positions, PCB mount (Lorlin).
Case, plastic, 120x65x40mm.
PCB, order code 980062-1 (see Readers Services page).

Miscellaneous, mechanical

1 non-isolated wander socket.
1 isolated wander socket.
Brass or copper tubing, 4mm dia.
Coax cable, 50 Ω , RG174, length 1m.
2 spring washers, dia. 10mm and 6mm.
8 washers, int. dia. 2.5mm, 0.5mm thick.
1 Nylon/Polyamide clamp for 9.5mm cable.
1 bolt, M3x7.
1 spindle extension 6/4mm o.d./i.d. 22-29mm long.
1 Collar knob 31mm dia., with marker (OKW).
1 Collar knob, 31mm dia, w/o marker (OKW).
1 Cap for OKW knob, with marker.
1 Cap for OKW knob, w/o marker.
2 Wander plugs with side hole (Hirschmann).
Aluminium sheet, 1.5mm thick, unprocessed size 71x115mm.
1 BNC plug.

Suggested suppliers:

Conrad Electronic, Klaus-Conrad-Strasse 1, D-92240 Hirschau, Germany. Tel. +49 180 531 2111, fax +49 180 531 2110. Internet: www.conrad.de.
Bürklin, Schillerstr. 41, D-80836 München, Germany, Tel. +49 89 558 75-0, fax +49 89 558 75-421. Email info@buerklin.de. Internet: www.buerklin.de

tion may be useful at this point. This amplifier exhibits very low noise across its entire frequency range, and offers excellent large-signal behaviour considering its modest current consumption. This is achieved by operating the FET as a source follower passing a high and practically constant drain current: its operating resistance of 75 Ω exists in parallel with the base and emitter of the next transistor rather than with respect to ground. The BFR193 is an SMA bipolar RF transistor whose frequency response is 'linearised' by means of strong feedback ($R_5 \gg r_D$). In contrast with the FET, it is easily dimensioned to supply the necessary (but still quite low) voltage gain. Remember that the main purpose of the amplifier is to provide the best possible impedance match to the loop antenna, while ensuring that severe intermodulation owing to nearby multi-kilowatt transmitters (utility or broadcast) does not occur easily. High gains are not generally required or indeed desirable ahead of any SW receiver input!

Depending on the frequency range selected using rotary switch S1A-S1B (0.15-0.7 MHz, 0.5-1.7 MHz, 1.7-8.2 MHz or 7-30 MHz), different magnetic antennas are connected to the amplifier input. In the highest range, only the 1-turn loop is connected, while in the lowest range, the amplifier receives the voltage produced by two series-connected coils on a ferrite rod. A 700-pF (350+350) variable capacitor, C1-C2, enables the antenna circuit to be tuned across a frequency range with a high/low ratio of about 4.8. For the lower SW bands, a loop with 4 turns would appear to be the best choice. The solution adopted here is, however, more elegant, using a transformer (L1-L2) with a step-up ratio of 1:4.5. Interestingly, the combination of a 1-turn loop and the transformer yields roughly the same quality factor (Q) and output signal level as the classic 4-turn loop. In practice, the use of a single 1-turn loop for two SW ranges is simply convenient!

For medium-wave (MW) and long-wave (LW) reception, the traditional ferrite rod still offers good performance. Using a rod with a diameter of 10 mm and a length of 200 mm, made from 4B1 material ($\mu_i = 250$, Philips Components) an effective permeability, μ_e , of about 115 is obtained, which is equal to an air-cored inductor having a surface area of about 90 cm², or a diameter of 10.7 cm. If the self-resonance frequency of the ferrite rod is below 2 MHz, the upper limit of the MW band (approx. 1.7 MHz) can not be reached without appreciable attenuation. That is why the MW/LW ferrite antenna is not wound using ordinary enamelled copper wire, but a Teflon-

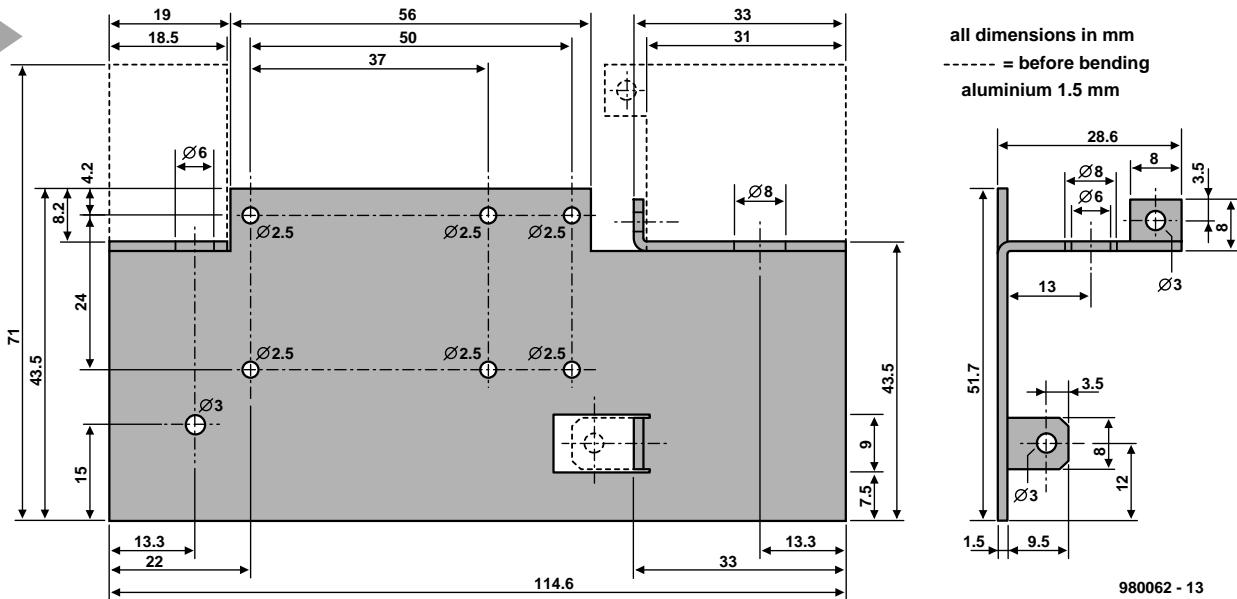


Figure 4. Drilling, cutting and bending details of the internal aluminium chassis.

coated alternative called Tefzel.

The amplifier's output signal appears across L6 at an impedance of about $50\ \Omega$. As you can see, it is coupled out inductively, the amplifier's supply voltage being applied to the primary of the 1:1 output transformer (L5-L6). This is coupled to the amplifier using an arbitrary length of $50\text{-}\Omega$ coax cable and a BNC or similar plug.

The value of R6 depends on the supply voltage used: use $220\ \Omega$ for 7.5-9 V, or $330\ \Omega$ if your supply (or receiver) delivers 10-15 V.

Coil winding, soldering & mechanical work

The construction of the Q-2 active antenna involves a fair bit of drilling, filing, cutting and winding of inductors. We'll start with the latter.

Three transformers, L1-L2, L3-L4 and L5-L6, are wound using two-hole ('binocular') ferrite cores as illustrated in **Figures 2a and 2b**. L3-L4 and L5-L6 are wound using bifilar wire which is easily made by twisting together two lengths of wire until a pitch of 3 to 5 turns per cm is obtained. After winding, the wire ends have to be identified with the aid of a multi-

meter. Winding data and materials used are stated in the Components List.

The coils on the ferrite rod (L7-L8) are wound in 'compartments' of formers normally used for pot cores (**Figure 2c**). L7 has four compartments with 25 turns each of 0.3 mm dia. (30AWG) Teflon-coated copper wire. The smaller coil, L8, has a total of 36 turns of ordinary 0.6-mm copper lacquer wire divided equally over two compartments. Note that two compartments remain empty.

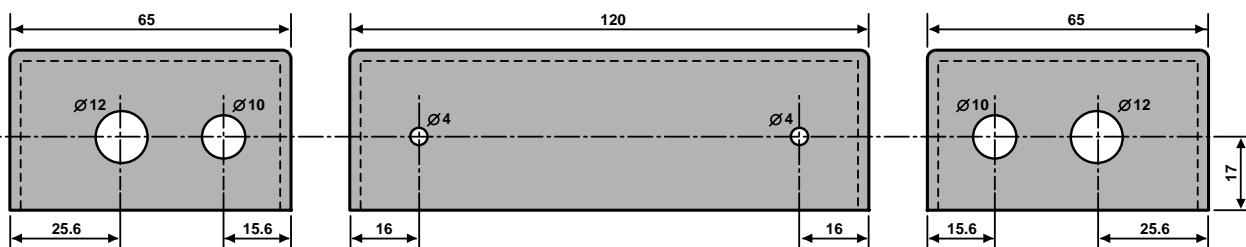
Having made these inductors you are ready to tackle the circuit board. The copper track layouts and component mounting plan of the double-sided PCB are given in **Figure 3**. This PCB is available ready-made from the Publishers. The amplifier proper is largely built from SMA (surface mount assembly) parts. To facilitate soldering by hand, the relevant copper spots are purposely made a little larger than usual for SMA components. To keep its cost within reason, the PCB is not through-plated, and a total of seven component wires, plus the wire ends of L3-L4, have to be soldered at both sides of the board.

Using aluminium

sheet with a thickness of 1.5 mm, a chassis is cut, drilled and bent as illustrated in **Figure 4**. Six holes with a diameter of 2.5 mm allow one of two types of 'Hopt' variable (tuning) capacitor to be firmly secured. Similar tuning capacitors from other manufacturers may require different mountings. One of the Hopt types the author picked up at a rally has only two AM sections, the other, two AM sections and two FM sections. Both are equally suitable. The AM sections are connected in parallel to produce a maximum tuning capacitance of about 700 pF, to be connected between ground and the PCB terminal marked 'CVAR'. A large knob makes for precise tuning, hence two 0.5 mm thick washers are used to make sure the centre of the tuning capacitor spindle is exactly half-way the height of the enclosure. The drilling details for the plastic case itself are shown in **Figure 5**. Seven holes have to be drilled, including one to pass the output coax cable. One additional, larger, hole may be required for a pivot assembly, a turntable or ball-bearing that enables the antenna to be rotated.

The internal construction of the Omega-2 amplifier is further illustrated in **Figure 6**. The two wander sockets are cut to a total length of 14 mm. The

Figure 5. Drilling details for the plastic case.



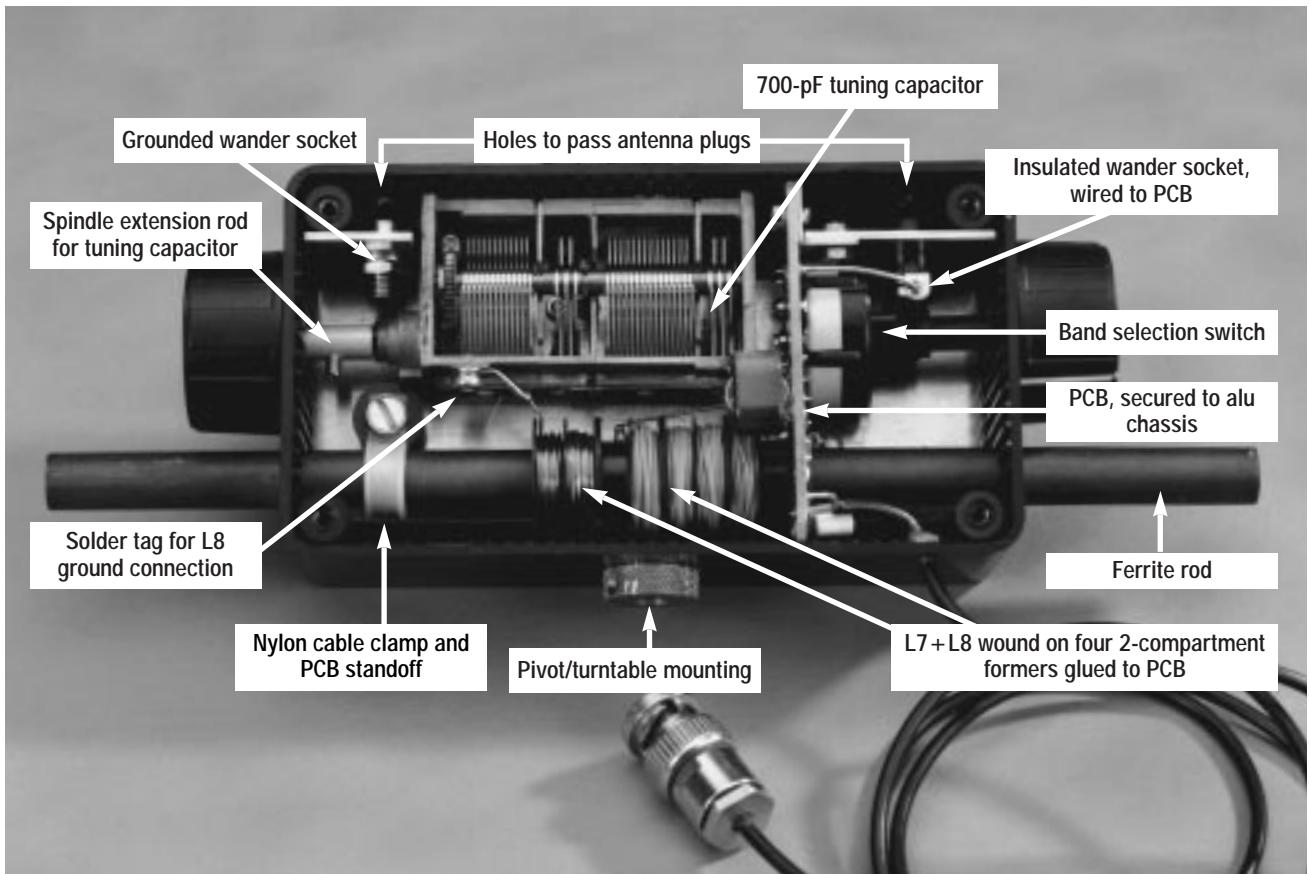


Figure 6. Internal view of the author's well-tried prototype of the Omega-2.

spindle length of the band selection switch is reduced by 13 mm. The insulated wander socket (to the right in the picture) is fitted with a solder tag for wiring to the PCB. In the suggested construction, there is no room for the M10 nut that comes with the rotary switch. Consequently, the locking ring is either omitted or secured in position '4' using two-component glue. The four 2-compartment formers (for pot cores) are first glued together, and

then to the PCB. Two compartments remain empty. Later, the ferrite rod is passed through the formers and the holes in the case panels and the PCB, before it is secured with a nylon cable strap.

The loop antennas

The shortwave antenna for the

Omega-2 is made by bending 4-mm dia. brass or copper tubing, or massive copper, using a bottle or similar round object as a 77-mm dia. bending aid. Before you start bending the tube, mark the locations of the corners at ± 90 and ± 300 mm. The final size of the antenna should be 201x261 mm measured from the tube centres, although a few millimetres tolerance is perfectly acceptable. The tube ends are cut off until they are 82 mm apart. Using an electric cooking plate or similar heating

Figure 7. Circuit diagram of the Omega-3 shortwave active antenna. To preserve the antenna's Q factor, the band selection switch should be a heavy-duty double-pole changeover type, preferably with silver-plated contacts. The suggested power supply circuit is inside the Sony ICF SW-100 receiver.

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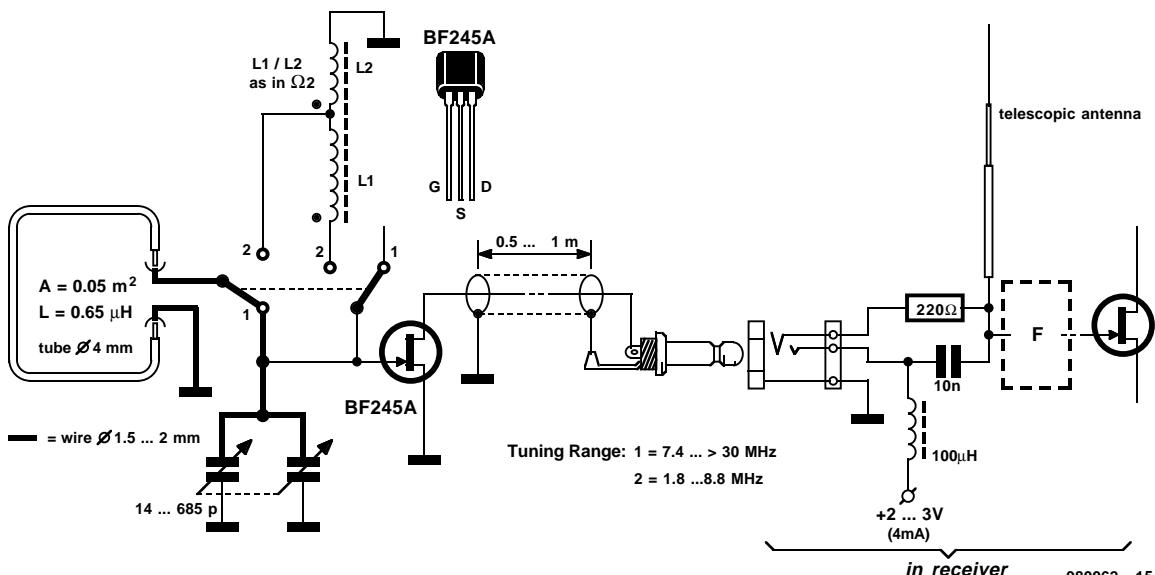


Figure 8. Omega-3 short-wave active magnetic antenna: easily stowed away in your holiday luggage, excellent SW reception guaranteed!

device the antenna and the wander plugs are preheated and then soldered.

An alternative to the ferrite rod is the 'classic' MW loop antenna consisting of 17 turns of 0.6-mm dia. enamelled copper wire wound on a wooden frame of dimensions 22x22x4 cm which is either home-made or obtained from a handicraft shop. The turns should be spaced by about 2 mm, and are best held in position by grooves cut in the four corners of the frame. This antenna will typically produce a signal level which is four times higher than that of the ferrite rod. Like the 1-turn loop for the two SW ranges, the MW window antenna is plugged into the Omega-2 amplifier box by means of two banana plugs. To use this excellent antenna, select the 7-30 MHz range. The finished MW loop is pictured in the introductory photograph, together with the Omega-2 amplifier. Its frequency coverage is 0.51-1.9 MHz.

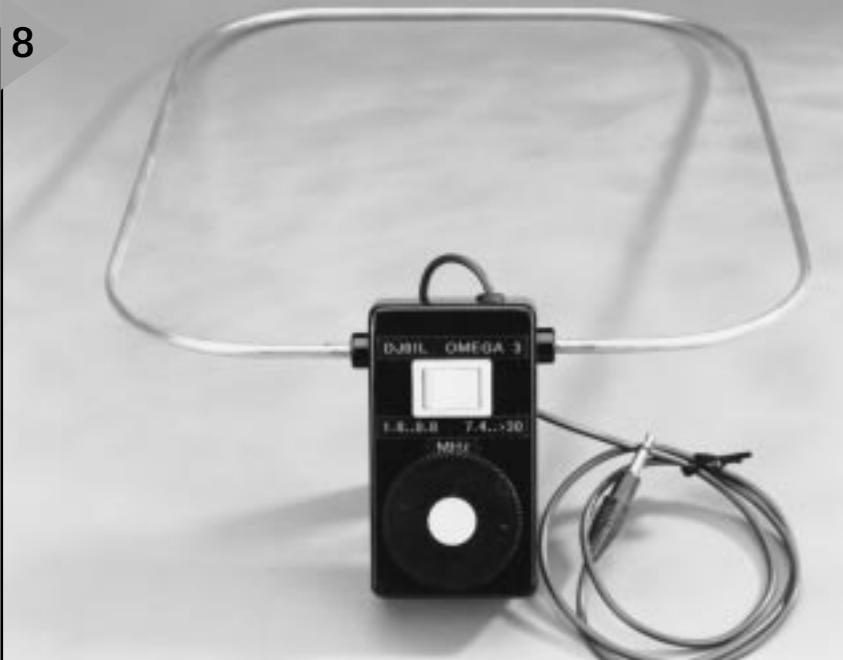
W - 3 ANTENNA FOR SW ONLY

Abroad, in a hotel with awful interference levels caused by airco systems and TV sets, or in a modern office, where computer noise thwarts any attempt at serious shortwave reception, you may expect little from your pocket-size shortwave receiver with its telescopic antenna, or even a wire antenna with a length of 5 m.

If your receiver has a socket for an external active antenna, you should not fail to experiment with very simple magnetic antennas based on FETs. As already mentioned, voltage gain is not required because the small receiver will be designed to handle small signals.

Figure 7 shows the circuit diagram of the Omega-3 active antenna. As you can see, it is simpler than the Omega-2, mainly because the LW and MW bands are not covered. For holiday use, however, the Omega-3 is the perfect choice!

Offering a transconductance of about 0.4 mS the BF245 FET supplies a gain of about 0.8 times at a load imped-



ance of 200Ω presented by the Sony ICF-SW100 receiver. The internal FET amplifier has a fairly high and frequency-dependent input impedance to match the built-in telescopic antenna. When an external active antenna is connected, its mono jack plug connects the 220Ω resistor to ground, causing a nearly constant load of $200-220 \Omega$ to be presented to the active antenna output, while reducing the influence of the telescopic antenna. High-pass and VHF trap filters (block F) leave a usable bandwidth of 1.6 to 30 MHz. The CCITT weighted sensitivity of the author's ICF-SW100 is around $0.25 \mu\text{V}$ at the input jack, for $(S+N)/N = 10 \text{ dB}$ at 80% amplitude modulation.

Compared with the receiver's telescopic antenna, the Omega-3 guarantees a noticeable volume increase, not even mentioning much reduced background interference levels.

The few parts that make up the Omega-3 are connected 'in the air'. As shown in Figure 8, the antenna is plugged in at the sides of the case.

(980062-1)

References:

- [1]. Wideband active rod antenna, *Elektor Electronics* May 1991.
- [2]. RC high-pass filter for active antennas, *Elektor Electronics* February 1992.

More interesting articles on antenna design which appeared in *Elektor Electronics*:

- Experimental quadrifilar ferrite T/R antenna, November 1991
- The QTC Loop Antenna, June 1991.
- An experimental all-waveband ferrite rod antenna, May 1990.
- The miser's T/R Loop Antenna, November 1990.
- A compact spiral T/R HF antenna, November 1992.
- Mark-Two 80/40 QTC Loop Antenna, July/August 1992.
- Wideband active telescopic antenna, July/August 1992.
- External ferrite aerial units for SW/MW/SW radios, May 1993.
- Small loop antennas for MW AM BCB, LF and VLF reception, June and July/August 1994.
- Ultima Loopstick VLF Antenna, July/August 1998.

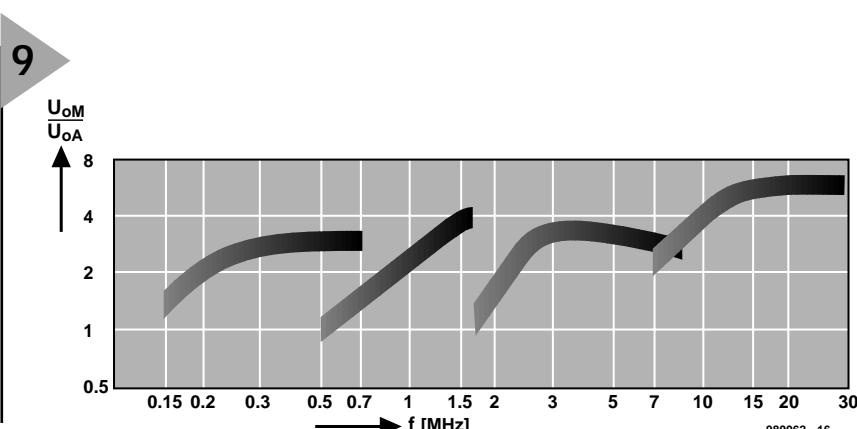


Figure 9. Output voltage (U_{oM}) of the Omega-3 active magnetic antenna installed in a living room, compared with an active rod antenna (U_{oA}) installed on the roof.